10-03-00

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jc839 U.S. PTO 10/02/00

Attorney's Docket No. UC98-194-2US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

jc927 U.S. PTO 09/677288 10/02/00

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of Inventor(s):

ANDREW A. FRANK

For (title):

CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES

1. Type of Application

This new application is for a(n):

_ Original (nonprovisional)
_ Design
_ Plant
_ Divisional
X Continuation of PCT in US
_ Continuation-in-part (CIP)

CERTIFICATION UNDER 37 CFR 1.10

I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date OCTOBER 2, 2000 in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EL641403544US addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

John P. O'Banion
(Type or print name of person mailing paper)

(Signature of person mailing paper)

NOTE: Each paper or fee referred to as enclosed herein has the number of the "Express Mail" label placed thereon prior to mailing. 37 CFR 1.10(b).

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2. **Papers Enclosed Which Are Required For Filing Date Under 37 CFR 1.53(b) (Regular) or 37 CFR 1.153 (Design) Application**

25 Pages of specification

6 Pages of claims

1 Pages of Abstract

9 Sheets of drawing

X formal

_ informal

_ The enclosed drawing(s) include photograph(s), and there is also attached a "PETITION TO ACCEPT PHOTOGRAPH(S) AS DRAWING(S)." 37 C.F.R. 1.84(b).

3. **Additional papers enclosed**

X Preliminary Amendment

_ Information Disclosure Statement

_ Form PTO - 1449

_ Citations

_ Authorization of Attorney(s) to Accept and Follow Instructions from Representative

_ Special Comments

_ Other

4. **Declaration Or Oath**

X Enclosed

executed by:

X inventor(s)

_ legal representative of inventor(s). 37 CFR 1.42 or 1.43.

_ joint inventor or person showing a proprietary interest on behalf of inventor who refused to sign or cannot be reached.

_ this is the petition required by 37 CFR 1.47 and the statement required by 37 CFR 1.47 is also attached. (See item 18 below for fee.)

__ Copy from a prior application (37 CFR 1.63(d)) (divisional or continuation only)

__ Not Enclosed.

__ Application is made by a person authorized under 37 CFR 1.41(c) on behalf of all of the above named inventor(s). (The declaration or oath, along with the surcharge required by 37 CFR 1.16(e) can be filed subsequently).

__ Attached is a showing that the filing is authorized. (Not required unless called into question. 37 CFR 1.41(d)).

5. Inventorship Statement

The inventorship for all the claims in this application are:

X The same

or

__ Are not the same. An explanation, including the ownership of the various claims at the time the last claimed invention was made,

__ is submitted.

__ will be submitted.

6. Language

X English

__ non-English

__ the attached translation is a verified translation. 37 CFR 1.52(d).

7. Assignment

X An assignment of the invention to: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

X is attached. A separate "ASSIGNMENT COVER LETTER ACCOMPANYING NEW PATENT APPLICATION" is also attached.

__ will follow.

8. Benefit of Prior U.S. Application(s) (35 U.S.C. 119(e), 120 or 121)

NOTE: "In order for an application to claim the benefit of a prior filed copending national application, the prior application must name as an inventor at least one inventor named in the later filed application and disclose the named inventor's invention claimed in at least one claim of the later filed application in the manner provided by the first paragraph of 35 U.S C. 112 " 37 CFR 1.78(a).

NOTE: "In addition, the prior application must be (1) complete as set forth in § 1.51, or (2) entitled to a filing date as set forth in § 1.53(b) and include the basic filing fee set forth in § 1.16, or (3) entitled to a filing date as set forth in § 1.53(b) and have paid therein the processing and retention fee set forth in § 1.21(l) within the time set forth in § 1.53(d)." 37 CFR 1.78(a).

NOTE: "Any nonprovisional application claiming the benefit of one or more prior filed copending provisional applications must contain or be amended to contain in the first sentence of the specification following the title a reference to each such prior provisional application, identifying it as a provisional application, and including the provisional application number (consisting of the series code and serial number) and filing date." 37 CFR 1.78(a)(4).

NOTE: "Any nonprovisional application claiming the benefit of one or more prior filed copending nonprovisional applications or international applications designating the United States of America must contain or be amended to contain in the first sentence of the specification following the title a reference to each such prior application, identifying it by application number (consisting of the series code and serial number) and filing date or international application number and international filing date and indicating the relationship of the applications. Cross-references to other related applications may be made where appropriate. (See §1.14(b))." 37 CFR 1.78(2).

X Applicant(s) hereby claim(s) the benefit of the filing date of prior U.S. Applications and/or PCT International Applications designating the U.S.:

1. (a) Application History (title as originally filed and as last amended, serial number, and filing date of all prior applications):

Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Ser. No.: PCT/US99/09889
Filed: APRIL 19, 1999

(b) Name of applicant(s) (as originally filed and as last amended), and current correspondence address of applicant(s):

Name: ANDREW A. FRANK
Address: 44578 COUNTRY CLUB DRIVE
EL MACERO, CA 95618

2. (a) Application History (title as originally filed and as last amended, serial number, and filing date of all prior applications):

Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Ser. No.: 09/063,993
Filed: APRIL 21, 1998

(b) Name of applicant(s) (as originally filed and as last amended), and current correspondence address of applicant(s):

Name: ANDREW A. FRANK
Address: 44578 COUNTRY CLUB DRIVE
EL MACERO, CA 95618

NOTE: The proper reference to a prior filed PCT application which entered the U.S. national phase is the U.S. serial number and the filing date of the PCT application which designated the U.S.

NOTE: (1) Where the application being transmitted adds subject matter to the International Application then the filing can be as a continuation-in-part or (2) it is desired to do so for other reasons, then the filing can be as a continuation.

NOTE: The deadline for entering the national phase in the U.S. for an international application was clarified in the Notice of April 28, 1987 (1079 O.G. 32 to 46) as follows:

"The Patent and Trademark Office considers the international application to be pending until the 22nd month from the priority date if the United States has been designated and no Demand for International Preliminary Examination has been

filed prior to the expiration of the 19th month from the priority date and until the 32nd month from the priority date if a Demand for International Preliminary Examination which elected the United States of America has been filed prior to the expiration of the 19th month from the priority date, provided that a copy of the international application has been communicated to the Patent and Trademark Office within the 20 or 30 month period respectively. If a copy of the international application has not been communicated to the Patent and Trademark Office within the 20 or 30 month period, respectively, the international application becomes abandoned as to the United States 20 or 30 months from the priority date, respectively. These periods have been placed in the rules as paragraph (h) of § 1.494 and paragraph (i) of § 1.495. A continuing application under 35 U.S.C. 365(c) and 120 may be filed anytime during the pendency of the international application."

9. Priority Claim for Prior Application (35 U.S.C. 119)

___ The prior U.S. application(s), including any prior International Application designating the U.S. identified above in item 8, in turn itself claim(s) foreign priority (ies) as follows:

(country)	(appln no.)	(filed on)
(country)	(appln no)	(filed on)
(country)	(appln. no)	(filed on)

The certified copy (ies)

_ is (are) attached.

_ has (have) been filed on _____ in prior application serial number _____ which was filed on _____.

_ will follow.

WARNING: The certified copy of the priority application which may have been communicated to the PTO by the International Bureau may not be relied on without the need to file a certified copy of the priority application in a continuing application. This is so because the certified copy of the priority application communicated by the International Bureau is placed in a folder and is not assigned a U.S. serial number unless the national stage is entered. Such folders are disposed of if the national stage is not entered. Therefore, such certified copies may not be available if needed later in the prosecution of a continuing application. An alternative would be to physically remove the priority documents from the folders and transfer them to the continuing application. The resources required to request transfer, retrieve the folders, make suitable record notations, transfer the certified copies, enter and make a record of such copies in the continuing application are substantial. Accordingly, the priority documents in folders of international applications which have not entered the national stage may not be relied on. Notice of April 28, 1987 (1079 O.G. 32 to 46).

10. Further Inventorship Statement Where Benefit of Prior Application(s) Claimed

NOTE: "If the continuation, continuation-in-part, or divisional application is filed by less than all the inventors named in the prior application, a statement must accompany the application when filed requesting deletion of the names of the person or persons who are not inventors of the invention being claimed in the continuation, continuation-in-part, or divisional application." 37 CFR 1.62(a) [emphasis added] (dealing with the file wrapper continuation situation).

NOTE: "In the case of a continuation-in-part application which adds and claims additional disclosure by amendment, an oath or declaration as required by § 1.63 must be filed. In those situations where a new oath or declaration is required due to additional subject matter being claimed, additional inventors may be named in the continuing application. In a continuation or divisional application which discloses and claims only subject matter disclosed in a prior application, no additional oath or declaration is required and the application must name as inventors the same or less than all the inventors in the prior application." 37 CFR 1.60(c). (dealing with the continuation situation).

(complete applicable item (a) or (b) below)

(a) ___ This application discloses and claims only subject matter disclosed in the prior application whose particulars are set out above and the inventor(s) in this application are

___ the same

___ less than those named in the prior application and it is requested that the following inventor(s) identified above for the prior application be deleted:

Name:

Name:

Name:

(b) ___ This application discloses and claims additional disclosure and a new declaration or oath is being filed. With respect to the prior application whose particulars are set out above, the inventors in this application are

___ the same

___ add the following inventors

Name:

Name:

Name:

11. Maintenance of Copendency of Prior Application

NOTE: The PTO finds it useful if a copy of the petition filed in the prior application extending the term for response is filed with the papers constituting the filing of the continuation application. Notice of November 5, 1985 (1060 O.G 27).

___ Extension of time in prior application

(This item must be completed and the necessary papers filed in the prior application if the period set in the prior application has run)

___ A petition, fee and response has been filed to extend the term in the prior application until _____.

___ A copy of the petition for extension of time in the prior application is attached.

(complete this item and file conditional petition in prior application if previous item not applicable)

___ Conditional Petition For Extension Of Time In Prior Application

___ A conditional petition for extension of time is being filed in the pending prior application.

12. Abandonment of Prior Application (if applicable)

___ Please abandon the prior application at a time while the prior application is pending or when the petition for extension of time or to revive in that application is granted and when this application is granted a filing date so as to make this application copending with said prior application.

NOTE: According to the Notice of May 13, 1983, (103, TMOG 6-7), the filing of a continuation or continuation-in-part application is a proper response with respect to a petition for extension of time or a petition to revive and should include the express abandonment of the prior application conditioned upon the granting of the petition and the granting of a filing date to the continuing application.

NOTE: "A registered attorney or agent acting under the provisions of § 1.34(a), or of record, may also expressly abandon a prior application as of the filing date granted to a continuing application when filing such a continuing application." 37 CFR 1.138.

13. Petition For Suspension Of Prosecution For The Time Necessary To File An Amendment (if applicable)

WARNING: "The claims of a new application may be finally rejected in the first Office Action in those situations where (1) the new application is a continuing application of, or a substitute for, an earlier application, and (2) all the claims of the new application (a) are drawn to the same invention claimed in the earlier application, and (b) would have been properly rejected on the grounds of art of record in the next Office Action if they had been entered in the earlier application." MPEP § 706.07(b).

NOTE: Where it is possible that the claims on file will give rise to a first action final for this continuation application and for some reason an amendment cannot be filed promptly (e.g., experimental data is being gathered) it may be desirable to file a petition for suspension of prosecution for the time necessary.

(check the next item, if applicable)

___ There is provided herewith a Petition to Suspend Prosecution For The Time Necessary To File An Amendment (New Application Filed Concurrently)

14. Notification in Parent Application of this Filing (if applicable)

___ A notification of the filing of this application is being filed in the parent application from which this application claims priority under 35 U.S.C. 120.

15. Fee Calculation (37 CFR 1.16)

A. X Regular Application

CLAIMS AS FILED

	Number filed		Number Extra		Rate		Basic Fee $ 710.00
Total Claims 37 CFR 1.16(c)	22	- 20 =	2	X	$18.00	=	36.00
Independent Claims (37 CFR 1.16(b))	7	- 3 =	4	X	$80.00	=	320.00
Multiple dependent claim(s), if any (37 CFR 1.16(d))				+	$270.00	=	

__ Amendment canceling extra claims enclosed.

__ Amendment deleting multiple-dependencies enclosed.

__ Fee for extra claims is not being paid at this time.

Filing Fee Calculation $ **1,066.00**

B. __ Design application
($320.00 - 37 CFR 1.16(f))

Filing Fee Calculation $ _____

C. __ Plant application
($490.00 - 37 CFR 1.16(g))

Filing Fee Calculation $ _____

16. Small Entity Statement(s)

X Verified Statements(s) that this is a filing by a small entity under 37 CFR 1.9 and 1.27

X is(are) attached.

___ will follow.

__ Status as a small entity was claimed in prior application serial number _____ filed on _____, from which benefit is being claimed for this application under 35 U.S.C. 119(e), 120, 121 or 365(c) and which status as a small entity is still proper and desired. A copy of the verified statement in the prior application is included.

Filing Fee Calculation (50% of **A, B** or **C** above) $ 533.00

17. **Request for International-Type Search (37 CFR 1.104(d))**

_ Please prepare an international-type search report for this application at the time when national examination on the merits takes place.

18. **Fee Payment Being Made At This Time**

_ Not Enclosed

_ No filing fee is to be paid at this time. (This and the surcharge required by 37 CFR 1.16(e) can/will be paid subsequently.)

X Enclosed

X	basic filing fee	$ 533.00
_	recording assignment ($40.00; 37 CFR 1.21(h))	$ _____
_	petition fee for filing by other than all the inventors or person on behalf of the inventor where inventor refused to sign or cannot be reached. ($130.00; 37 CFR 1.47 and 1.17(h))	$ _____
_	for processing an application with a specification in a non-English language. ($130.00; 37 CFR 1.52(d) an 1.17(k))	$ _____
_	processing and retention fee ($130.00; 37 CFR 1.53(d) and 1.21(l))	$ _____
_	fee for international-type search report. ($40.00; 37 CFR 1.21(e))	$ _____
	Total Fees Enclosed	$ 533.00

19. **Method of Payment of Fees**

X Check in the amount of $ 533.00

_ Charge Account No. _____ in the amount of $ _____.
A duplicate of this transmittal is attached.

20. **Authorization to Charge Additional Fees**

_ The Commissioner is hereby authorized to charge the following additional fees by this paper and during the entire pendency of this application to Account No. _____;

_ 37 CFR 1.16(a), (f) or (g) (filing fees)

_ 37 CFR 1.16(b), (c) and (d) (presentation of extra claims)

_ 37 CFR 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)

_ 37 CFR 1.18 (application processing fees)

_ 37 CFR 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 CFR 1.311(b))

21. Instructions As To Overpayment

_ credit Account No. _____

X refund

22. Incorporation By Reference of Papers Identified Herein

Applicant(s) hereby incorporate(s) by reference all papers which are identified in this New Application Transmittal.

23. Correspondence Address

Please use the following correspondence address for all communications:

John P. O'Banion, Reg. No. 33,201
O'BANION & RITCHEY LLP
400 Capitol Mall, Suite 1550
Sacramento, CA 95814
(916) 498-1010

Dated: 10/2/00.

SIGNATURE OF ATTORNEY
John P. O'Banion, Reg. No. 33,201

Applicant: ANDREW A. FRANK
Serial No.:
Filed:
Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Group:
Examiner:
Docket No. UC98-194-2US

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(b))-INDEPENDENT INVENTOR

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for the purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention described in

[X] the specification filed herewith, with the title listed above.

[ ] the application identified above.

[ ] the patent identified above.

I have not assigned, granted, conveyed or licensed, and I am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or to any organization who could not qualify as a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

[ ] no such person, concern, or organization

[X] persons, concerns or organizations listed below[1]

NAME: The Regents of the University of California
ADDRESS: 1111 Franklin Street, 12th Floor
Oakland, CA 94607-5200

[ ] Individual [ ] Small Business Concern [X] Nonprofit Organization

[1] Separate verified statements are required from each named person, concern or organization having rights to an invention averring to their status as small entities (37 CFR 1.27).

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Inventor: ANDREW A. FRANK

Andrew A. Frank
Signature of Inventor

Date: 9/19/00

PATENT

Applicant: ANDREW A. FRANK
Serial No.:
Filed:
Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Group:
Examiner:
Docket No. UC98-194-2US

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) AND 1.27(d) - NONPROFIT ORGANIZATION

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

NAME OF ORGANIZATION: The Regents of the University of California
ADDRESS OF ORGANIZATION: 1111 Franklin Street, 12th Floor
Oakland, CA 94607-5200

TYPE OF ORGANIZATION

[X] UNIVERSITY OR OTHER INSTITUTION OF HIGHER LEARNING

[X] TAX EXEMPT UNDER INTERNAL REVENUE SERVICE CODE [26 USC 501(a) and 601(c)(3)]

[ ] NONPROFIT SCIENTIFIC OR EDUCATIONAL UNDER STATUTE OF STATE OR THE UNITED STATES OF AMERICA
[ ] NAME OF STATE: _____
[ ] CITATION OF STATUTE: _____

[ ] WOULD QUALIFY AS NONPROFIT SCIENTIFIC OR EDUCATIONAL UNDER STATUTE OF STATE OF THE UNITED STATES OF AMERICA IF LOCATED IN THE UNITED STATES OF AMERICA
[ ] NAME OF STATE: _____
[ ] CITATION OF STATUTE: _____

I hereby declare that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR 1.9(e) for purposes of paying reduced fees under Section 41(a) or (b) of Title 35, United States Code, with regard to the invention described in

[X] the specification filed herewith, with the title listed above.

[ ] the application identified above.

[ ] the patent identified above.

I hereby declare that rights under contract or law have been conveyed to and remain with the nonprofit organization with regard to the invention identified above.

If the rights held by the nonprofit organization are not exclusive, each individual, concern or organization having rights to the invention is listed below[1] and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(d) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

NAME: N/A

ADDRESS: _____

_____

[ ] Individual [ ] Small Business Concern [ ] Nonprofit Organization

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28)

I hereby declare that all statements made herein of my own knowledge are and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING: Linda S. Stevenson

TITLE IN ORGANIZATION: Manager, Patent Prosecution
ADDRESS OF PERSON SIGNING: Office of the President
University of California
1111 Franklin Street, 5th Floor
Oakland, CA 94607-5200

SIGNATURE: Linda S Stevenson. DATE: September 22, 2000

[1] Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities (37 CFR 1.27).

PATENT

Applicant: ANDREW A. FRANK
Serial No.:
Filed:
Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Group:
Examiner:
Docket No.: UC98-194-2US

Assistant Commissioner for Patents
Washington, D.C. 20231

FIRST PRELIMINARY AMENDMENT

Dear Sir:

Please enter the following Preliminary Amendment in connection with the above-identified U.S. patent application:

IN THE SPECIFICATION:

On page 1, please delete lines 6 and 7 and insert the following:

--This application claims priority from, and is a 35 U.S.C. § 111(a) continuation of, co-pending PCT international application serial number PCT/US99/09880 filed on April 19, 1999 which designates the U.S., which is a continuation-in-part of U.S. application serial number 09/063,993 filed on April 21, 1998, now U.S. Patent No. 6,054,844, from which priority is also claimed.--

REMARKS

This Preliminary Amendment is submitted identify the prior and co-pending applications from which this application claims priority. Entry is respectfully requested.

Date: 2 OCTOBER 2000

Respectfully submitted,

Steven L. Silen
44,343

John P. O'Banion, Reg. No. 33,201
O'BANION & RITCHEY LLP
400 Capitol Mall, Suite 1550
Sacramento, CA 95814
(916) 498-1010

TITLE OF THE INVENTION

CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of copending application serial number 09/063,993 filed on April 21, 1998.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

REFERENCE TO A MICROFICHE APPENDIX

Not Applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains generally to vehicle powertrains and transmissions, and more particularly to a method and apparatus for controlling the operating characteristics of an internal combustion engine coupled to a drive train having a mechanical or electrical continuously variable transmission or a standard automatic transmission.

2. Description of the Background Art

The concept of an engine and a "continuously variable transmission" is a very old concept invented in the 1900's, but the theoretical efficiency of the engine, performance and driveability could never be obtained automatically. This can be seen with reference to the conventional powertrain and transmission shown in FIG. 1 where an internal combustion engine 10 has an output shaft 12 that drives a decoupling/starting clutch or torque converter 14, which is in turn coupled to the input shaft 16 of a continuously variable transmission (CVT) or automatic transmission (AT) 18, which in turn has an output driving a drive shaft or differential 20 coupled to a final drive wheel 22 (e.g., axle and tire). The deficiencies of such a configuration are caused by the dynamic equation representing the engine/CVT system:

$$\alpha_{DS} = \frac{-\dot{R} I_E S_E + T_E R - T_{loss} - T_{RL}}{I_{DS} + R^2 I_E}, \qquad \dot{R} = \frac{dR}{dt}$$

where α_{DS} = acceleration of the vehicle reflected to the drive shaft, $R = \frac{S_E}{S_{DS}}$, I_E = engine inertia, I_{DS} = vehicle inertia at the driveshaft, S_E =engine speed, S_{DS}= drive shaft speed, T_E = engine torque, T_{loss} = torque losses, and T_{RL} = road load torque at the driveshaft. Because the first term $-\dot{R} I_E S_E$ and the second term $T_E R$ generally oppose each other, the acceleration of the car and the torque and speed of the engine are difficult to control simultaneously. As a result, the best efficiency and minimum emissions for a gasoline or diesel engine cannot be realized without a sacrifice in performance. This can be seen with further reference to FIG. 2 and FIG. 3 which show operating characteristics of the engine as a function of engine speed and torque, where *WOT* = wide open throttle and denotes the maximum torque line, *IOL* = ideal torque/speed

operating line and denotes where the best efficiency and/or least emissions (minimum brake specific fuel consumption or BSFC) occurs, and *POL* = practical operating line due to engine/transmission characteristics. Note in FIG. 3 that point *A* is less efficient than point *B* but must be used to provide proper vehicle behavior (transient performance).

BRIEF SUMMARY OF THE INVENTION

The foregoing deficiencies can be overcome in accordance with the present invention by inserting an electric motor or motor/generator, a battery, and associated controls between the engine and the continuously variable or automatic transmission. It will be appreciated that when the term "battery" is used herein, the term can include any energy storage device such as an ultra-capacitor, electrochemical battery, or the like.

In the preferred embodiment, a motor/generator is controlled to counteract the negative effect of the $-\dot{R} I_E S_E$ in the dynamic equation. The motor/generator can then be used to allow the engine to operate at "wide open throttle" (*WOT*), or along the "Ideal Torque/Speed Operating Line" (*IOL*) for best efficiency and lowest emissions, or along any other predetermined operation line. In this way, the engine can be run continuously while energy flows into or out of the battery energy storage system connected to the electric motor/generator. If the battery is large enough to drive the vehicle a long distance, then the efficiency of energy into and out of the battery is high since the battery internal resistance is low. This concept is especially desirable for a charge depletion hybrid electric vehicle as described in my prior patent, U.S. No. 5,842,534 which is incorporated herein by reference, where the large battery pack is charged from stationary powerplants. The emissions of the gasoline or diesel engine can be controlled

effectively because the engine is operated at high load consistently. The present invention ensures that the gasoline or diesel engine is never operated at closed throttle at high speeds or operated at low efficiency low load conditions. If the power required is lower than the minimum power of the engine on the *IOL*, the engine is automatically decoupled and stopped (or idled if desired), and the vehicle is operated as an electric vehicle.

An object of the invention is to provide for simultaneous control of the acceleration, deceleration or braking of a vehicle and the torque and speed of the engine in a vehicle.

Another object of the invention is to control the torque of the electric motor/generator to provide acceleration, deceleration and braking of a vehicle having an engine, transmission and electric motor/generator.

Another object of the invention is to allow the engine in a vehicle to always operate at wide open throttle (*WOT*) or along the ideal torque/speed operating line (*IOL*) and to vary power by engine speed.

Another object of the invention is to provide for reduced emissions of an engine by restricting its operating range.

Another object of the invention is to provide for consistently high load operation of an engine.

Another object of the invention is to achieve high vehicle acceleration and deceleration performance from a hybrid electric vehicle using a combustion engine and electric motor.

Another object of the invention is to reduce battery cycling and improve battery life in a hybrid electric vehicle.

Another object of the invention is to allow a vehicle to sustain a charge on the batteries dependent on the driving load.

Another object of the invention is to improve the efficiency of a hybrid electric vehicle.

Another object of the invention is to maximize operating efficiency of the combustion engine in a hybrid electric vehicle at varying power levels, thereby providing for better fuel economy.

Another object of the invention is to maximize the range of a charge depletion hybrid electric vehicle as described in my prior patent, U.S. No. 5,842,534 which is incorporated herein by reference.

Further objects and advantages of the invention will be brought out in the following portions of the specification, wherein the detailed description is for the purpose of fully disclosing preferred embodiments of the invention without placing limitations thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood by reference to the following drawings, where like reference numbers denote like parts, which are for illustrative purposes only:

FIG. 1 is a functional block diagram of a prior art vehicle with a powertrain employing a continuously variable or multi-speed automatic transmission.

FIG. 2 is a graph showing the torque-speed efficiency map of a typical combustion engine showing maximum torque at wide open throttle (WOT) and an ideal operating line (IOL) which produces the best efficiency and minimum emissions for a given power of the engine shown in FIG. 1.

FIG. 3 is a graph showing the practical operating line (POL) required for the conventional vehicle shown in FIG. 1 compared with the ideal operating line (IOL).

FIG. 4 is a functional block diagram of a control apparatus in accordance with the present invention in a parallel hybrid configuration having a continuously variable transmission in the drive train

FIG. 5 is a functional block diagram of an alternative embodiment of the control apparatus shown in FIG. 4 in a series hybrid configuration having a continuously variable or automatic transmission in the drive train.

FIG. 6 is a functional block diagram of the control apparatus shown in FIG. 4 where the generator/motor and controller, and the motor/generator and controller are used as an electric continuously variable transmission.

FIG. 7 is a functional block diagram of an alternative embodiment of the invention functioning as a dual power parallel hybrid system.

FIG. 8 is a flow diagram showing the control method of the present invention.

FIG. 9 is a graph showing engine and electric motor/generator torque as a function of engine and transmission speed, as well as the operational boundary for acceleration and a typical acceleration/deceleration cycle for the apparatus shown in FIG. 4.

FIG. 10 is a graph showing the acceleration/deceleration cycle shown in FIG. 9 as a function of time.

FIG. 11 is a graph showing accelerator pedal change necessary to accomplish the acceleration/deceleration cycle shown in FIG. 9 as a function of time.

FIG 12 is a graph showing velocity of the vehicle having the operational characteristics shown in FIG. 9 as a function of time.

FIG. 13 is graph showing braking control characteristics for the control system shown in FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

Referring more specifically to the drawings, for illustrative purposes the present invention is embodied in the apparatus and method generally shown in FIG. 4 through FIG. 13. It will be appreciated that the apparatus and associated control method may vary as to their details without departing from the basic concepts as disclosed herein.

Referring first to FIG. 4, in accordance with the present invention an electric motor 24 is coupled to the input shaft 16 of the continuously variable transmission 18 so that it injects power in parallel with the drive train between engine 10 and continuously variable transmission 18. Electric motor 24 is powered by a battery 26, which would typically comprise a bank of batteries, ultra-capacitors or the like, such as those used in electric vehicles. Operation of electric motor 24 is controlled by a motor controller 28, which is a conventional electronic armature controller or the like, which is in turn controlled by a microprocessor- or other computer-based programmable system controller 30.

The size of electric motor 24 can vary and, while electric motor 24 can be a motor only, electric motor 24 is preferably a motor/generator that can also be used to charge battery 26. Therefore, all references to the terms "motor" or "motor controller" in the specification and claims are intended to encompass either a motor and a motor controller or a motor/generator and motor/generator controller, respectively. References herein made to "motor/generator" and

"motor/generator controller" are for purposes of describing the preferred embodiment of the invention. Electric motor 24 would, for example, be a conventional DC or AC or switch reluctance or other torque controlled high power traction motor/generator used in hybrid and electric vehicles.

It will be appreciated that an automatic transmission can be used in place of the CVT. Therefore, all references to "transmission" in the specification and claims are intended to encompass either a continuously variable transmission or an automatic transmission. References made herein to "continuously variable transmission" are for purposes of describing the preferred embodiment of the invention. It will also be appreciated that a mechanical CVT or automatic transmission 18 can be eliminated altogether and replaced by the motor (or motor/generator) and motor controller (or motor/generator controller) in combination with a generator (or generator/motor) and generator controller (or generator/motor controller) as will be discussed below with reference to FIG. 5 and FIG. 6.

In the embodiment shown in FIG. 4, system controller 30 processes a plurality of control and feedback signals. As shown, the primary input control signals are from the vehicle accelerator pedal 32 and brake pedal 34. It will be appreciated that other control signals may also be used for example, such as park, drive, performance and so forth. Based on these signals, system controller 30 sends a throttle control signal 36 to engine 10 to control the engine torque T_E, an engine engagement on/off signal 38 to clutch 14, a torque control signal 42 to motor controller 28 to control motor torque T_M, and a rate of change of speed ratio control signal 44 to control the rate of change $\dot{R}$ of the speed ratio R of continuously variable transmission 18,

where $R = \frac{S_E}{S_{DS}}$, S_E = engine speed and S_{DS} = driveshaft speed. It should be noted that

$$S_{DS} = S_{CAR} \times C$$

where S_{CAR} is the speed of the vehicle and C is a constant dependent on the gear ratio of the final drive and tire radius for the vehicle. At the same time, system controller 30 senses engine speed S_E via speed signals 40, the ratio R via signals 46, and vehicle speed S_{CAR} via signals 48. Note that the system controller 30 may send an "on/off" signal to engine 10, but a separate starter motor is not needed; electric motor 24 can be used start engine 10 because it is coupled to engine output shaft 12 through clutch 14. The engine 10 may be turned "off" or idled when clutch 14 is opened.

Referring now to FIG. 5 and FIG. 6, the present invention can be extended to a series hybrid vehicle configuration as shown in which a generator 50 is used to provide charging capability for battery 26 as well as to provide a braking effect for engine 10 during deceleration. Operation of generator 50 is preferably controlled by a generator controller 52, which is a conventional electronic armature controller or the like. Generator controller 52 controls generator torque, T_G, in response to signals received from system controller 30 through torque control line 54. Note that $T_G = T_E$ in this configuration.

Preferably, generator 50 is of a generator/motor type so that operation can force engine 10 to achieve the desired speed quickly, thus providing for fast overall engine response. Therefore, all references to the terms "generator" or "generator controller" in the specification and claims are intended to encompass either a generator and a generator controller or a generator/motor and generator/motor controller, respectively. References herein made to

"generator/motor" and "generator/motor controller" are for purposes of describing the preferred embodiment of the invention. Generator 50 would, for example, be a conventional DC or AC or switch reluctance or other torque controlled high power traction generator/motor used in hybrid and electric vehicles.

Note also the inclusion of an optional starter control line 56 for starting and shutting down engine 10. Where a generator 50 is of a generator/motor type, it may be possible to eliminate the need for a starter motor if the motor portion of generator 50 has a sufficiently high output.

In these embodiments of FIG. 5 and FIG. 6, engine 10 can be operated at high torque but at a power necessary to provide steady cruise speed. The engine torque and power may be small compared with the electric motor/battery power. A mechanical CVT or automatic transmission 18 may be used as shown in FIG. 5, or eliminated altogether as shown in FIG. 6 since generator 50 and motor (or motor/generator) 24 via the generator controller 52 and motor controller 28, respectively, together function as an electric CVT. In the embodiments of FIG. 5 and FIG. 6, generator 50 is used to control the engine power by temporarily putting energy into, or taking energy out of, battery 26 based on the power commanded by the driver.

Note that operation of the engine in the above configuration is considerably different than in a conventional series hybrid vehicle where the engine is always running at one speed. When the engine is operated at a constant speed, the efficient power output only occurs at one level. Thus the batteries will have to absorb excess power or provide additional power to drive the vehicle. This results in considerable deep battery cycling and attendant inefficiencies. In the present invention, however, the engine is used more and the batteries are shallow cycled.

Because the amount of power cycled by the batteries is greatly reduced with the present invention, the range per battery charge is increased. Battery life is increased as well.

Referring now to FIG. 7, the invention can also be applied to dual power parallel powertrain as shown. This embodiment provides torque from both the front wheels 58 of the vehicle 60 electrically from the electric motor (or motor/generator) 24 and the rear wheels 62 mechanically from engine 10 through clutch 12 and CVT 18. Note that the block shown as CVT 18 could be a conventional continuously variable or automatic transmission. Note also that the CVT 18 is connected only to engine 10; the road and tires effectively connect the front and rear wheels together through the road 64, with the road 64 effectively acting as a shaft. It will be appreciated that the drive wheels may also be reversed, with the electric motor at the rear and the engine and CVT at the front of the vehicle. In this case, the electric motor controls the engine through the CVT, the output of which is controlled through the road. Thus, this configuration is effectively that of a parallel hybrid configuration and would be controlled using a hybrid of the embodiments shown in FIG. 4 and FIG. 5. The electric motor 24 can once again control the overall force of the vehicle so that the concept of engine and vehicle control shown in FIG. 4 is accomplished. The engine can then operate on the *IOL* with modulating torque from the electric motor 24. The advantage of this system is a small engine-CVT system relative to the high power electric motor that can be used for high fuel efficiency and performance.

Referring now to FIG. 4, FIG. 8 and FIG. 9 together, system controller 30 implements the control and sensing functions of the invention using conventional hardware and/or software. In FIG. 8, A_C = accelerator pedal position and represents power or torque commanded by the driver (P_C or $+T_C$, respectively); B_C = brake pedal position representing negative torque commanded by

the driver ($-T_C$); T_M = electric motor torque; P_{EP} = the error or difference between the power commanded by the driver and the power along the *IOL* for the power control mode (P_C-P_{IOL}); T_{EP} = the error or difference between the torque commanded by the driver and the torque along the *IOL* for the torque control mode ($T_C - \frac{P_{IOL}}{S_E}$); P_{IOLE} = the power along the ideal operating line of the engine; P_{IOLM} = the power along the ideal operating line of the electric motor; *IRL* = the ideal regeneration line for braking; T_{EB} = the error or difference between the braking commanded by the driver and the braking along the *IRL* for the braking control mode (B_C-T_{IRL}); T_{IRL} = the torque along the ideal regeneration line for braking; K_1 = a gain adjustment for desired response time and stability of the circuit, K_2 = a gain adjustment set in response to $S_E \dot{R}$ in order to achieve the desired response characteristics in FIG. 9, T = the time constant of the filter, S = the Laplace transform of variable P_{EP} or T_E which is easily programmed by those skilled in the art; R = the ratio between engine speed and driveshaft speed; $\dot{R}$ = the rate of change of ratio R; C = a conversion constant to convert vehicle speed to driveshaft speed; S_E = engine speed; S_{DS} = drive shaft speed; S_{CAR} = vehicle speed; and K_B is a gain value for scaling. When the accelerator pedal is depressed, switches SW1 and SW2 go to the accelerator position. Switches SW3 and SW4 will be set according to whether the vehicle is in the electric or hybrid mode. Similarly, when the brake pedal is depressed, switches SW1 and SW2 go to the brake position. Each of these switches generally may be software switches in system controller 30. The IOL_E of the engine is obtained by testing the engine to determine the best efficiency and emissions at each speed. The IOL_M and IRL are obtained by testing the electric motor/generator and battery system to obtain the most energy into the battery at each speed. Note that the IOL_M is used when the vehicle is in

the electric drive mode where the vehicle is operated, generally, below freeway speeds until the batteries are depleted to a predetermined state as described in U.S. Patent No. 5,842,534.

There are many possible control algorithms for hybrid electric vehicles. The control objective here is to drive the vehicle using electric energy until the internal combustion engine is turned "on" and then drive the vehicle with the internal combustion engine as much as possible, automatically supplementing the internal combustion engine with electric energy when needed to maintain operation of the engine along the *IOL*. Significantly, energy may be put back into the batteries temporarily when the engine power is reduced in order to keep the engine on the IOL at all times in the hybrid mode. This kind of operation can significantly reduce emissions and increase engine efficiency.

It will be appreciated that there are many ways to determine when the engine would be "on". For purposes of the present invention, the control strategy of FIG. 8 will function with charge depletion HEV implementations as shown in my prior U.S. No. 5,842,534 as well as most conventional charge sustaining HEV implementations. For any given engine speed, there is only one power that falls on the *IOL*. The *IOL* is engine dependent, and is determined empirically from test data. In the preferred embodiment, the *IOL* is the line representing engine power output per speed that provides the best engine efficiency and low emissions. It will be appreciated, however, that the *IOL* could represent any desired engine operating condition at a particular engine speed. Since the power output varies as a function of speed and load on the engine, the present invention uses motor 24 as in FIG. 4, or generator 50 and/or motor 24 in FIG. 5 and FIG. 6, to vary the speed and power output of the engine to be on the IOL at all times when the engine is "on".

In operation, system controller 30 senses the acceleration command A_C from the accelerator pedal and the switches SW1 and SW2 shown in FIG. 8 go to the accelerator position. When power or a positive torque is commanded by the driver (P_C or $+T_C$) in the electric vehicle mode determined by SW3 and SW4 as the case may be depending upon whether or not the system is operating in the power control region or the torque control region shown in FIG. 9, the system is in an acceleration mode and the desired motor torque T_M is then determined at 114 according to

$$T_M = \frac{P_C}{S_E} + K_2 S_E \dot{R} \quad \text{or} \quad T_M = T_C + K_2 S_E \dot{R}$$

if the vehicle is in the hybrid-mode, then T_M is determined at 126 according to

$$T_M = \frac{P_C}{S_E} - T_{IOL_E} + K_2 S_E \dot{R} \quad \text{or} \quad T_M = T_C - T_{IOL_E} + K_2 S_E \dot{R}$$

The motor torque signal determined above is sent to motor controller 28 in FIG. 4 to vary the speed and power of engine 10 and to drive the car. The resultant change in electric motor torque in turn affects the vehicle dynamics at 102, which affect engine speed, vehicle speed and the ratio R at CVT 18. Taking the speed of the vehicle S_{CAR} as well as the ratio R at 102, in FIG. 8, engine speed S_E (which may also be the same as the motor speed S_M where they are on a common shaft) can be determined by applying a conversion constant C to the vehicle speed S_{CAR} at 104 to get the speed S_{DS} of driveshaft 20 of FIG. 4 (which is the output of CVT 18) and then multiplying the driveshaft speed S_{DS} by the ratio R at 106 in FIG. 8 to give the engine speed S_E. Now having engine speed S_E, at 108, 116 and 128 look-up tables containing the *IOL* entries for the hybrid mode, braking mode and the electric mode, respectively, are accessed to determine the

ideal engine power or torque output level for the given speed. Then, at 110 for the hybrid mode, 118 for the braking mode or 130 for the electric mode, the output of the corresponding look-up table is compared with either the power P_C (if in power control mode) or positive torque $+T_C$ (if in torque control mode) commanded by the driver with the accelerator pedal as sensed from accelerator pedal position A_C to determine a power error P_{EP} or a torque error T_{EP}. One manner in which P_{EP} or T_{EP} could be determined, for example, would be to use a potentiometer that produces an output signal in response to accelerator pedal position (P_C or T_C), and subtracting the appropriately scaled P_{IOL} or T_{IOL} from the look-up tables. Transducers, digital to analog converters and/or analog to digital converters, could also be used as is conventional in the signal acquisition and processing art. The corresponding error signal is then used to affect the rate of change $\dot{R}$ of the ratio R after filtering the signal at 112. CVT 18 of FIG. 4 thus responds in accordance with the adjustment of $\dot{R}$.

An important aspect of the control system is the control of the rate of change of ratio R or $\dot{R}$. This is accomplished by filtering the error signal between the commanded power PC or torque TC and the IOL power or torque. The signal filtering, which is in the form of

$$K_1 \bullet \frac{1}{TS+1}$$

is well known in the art of electrical engineering. It is understood that this filter is only representative of one form that may be placed at this point, and in practice the filter may include both linear and non-linear elements. The purpose of the filter is to allow the designer to control the ratio rate, $\dot{R}$. It is undesirable to change R quickly and, therefore, a filter is necessary to

provide the desired system response. The values of K_I and T are heuristically determined, as is the form of the filter (which is shown here as first order). Those skilled in the art will appreciate that filters of many other representations will work and can be selected depending on the desired response, and the scope of the present invention should not be limited by the use of this particular filter.

During braking, torque is being commanded at the wheels rather than engine power. Here, system controller 30 senses the braking command B_C from the brake pedal. When the driver commands negative torque $-T_C$, the system is in a deceleration (regeneration) mode and the switches go to the brake position. Here, control of the CVT and electric motor/generator reverses to produce a negative torque on the driveshaft, thus braking the vehicle. It will also be appreciated that a mechanical backup brake (not shown) for use in emergencies, panic stops and parking. The operation of the braking circuit is similar to that of the accelerator circuit except for the use of the ideal regeneration line IRL, which reflects the highest efficiency for a given power for regenerating energy into the batteries by the electric motor/generator.

For purposes of braking, the desired motor torque T_M is determined at 100 according to

$$T_M = \frac{T_C}{R} - K_2 S_E \dot{R}$$

and the signal is sent to motor/generator controller 28 to vary the speed and power of engine 10. The resultant change in electric motor/generator and engine torque again affect the vehicle dynamics at 102, to slow the car which affects motor and/or engine speed, vehicle deceleration and the ratio R at CVT 18. Here, however, engine speed S_E is used at 116 to access a look-up table containing entries representing the *IRL*, which is also an empirically determined table.

Then, at 118, the output of the look-up table is compared with the negative torque $-T_C$ commanded by the driver with the brake pedal as sensed from brake pedal position B_C to determine the braking torque error T_{EB}. The braking torque error signal T_{EB} is then scaled by a value of K_B through gain box 120 and used to affect the rate of change $\dot{R}$ of the ratio R after filtering at 112. It should be appreciated that the filtering in the brake torque control can be different if desired and that gain box 120 may contain additional filters.

Therefore, FIG. 8 and FIG. 9 represent the controls for the configuration shown in FIG. 4 and, in principle, the controls for the configurations expressed in FIG. 5 through FIG. 7 or other hybrid electric drive systems. Note that the configuration shown in FIG. 6 can be used directly with the control scheme shown in FIG. 8 and FIG. 9 discussed below since the mechanical CVT shown in FIG. 4 is simply replaced by its electrical equivalent. However, those skilled in the art will appreciate that slight modification of the control scheme shown in FIG. 8 and FIG. 9, consistent with the discussion herein, would be necessary for use with the configuration shown in FIG. 5, since both a mechanical CVT and its electrical equivalent are used. In FIG. 5, the generator/motor is used to control the engine along the IOL instead of the CVT. Energy will flow into and out of the battery a little more and most of the generator electric energy will go directly to driving the motor/generator The CVT or discrete automobile transmission will need an additional controller, which can be configured again similar to that shown in FIG. 8. Those skilled in the art will also appreciate that slight modification of the equations of control scheme shown in FIG. 8, consistent with the discussion herein, would be necessary for use with the configuration shown in FIG. 7 since the electric motor 24 is connected to the output of CVT 18 rather than the input. The operational characteristics shown in FIG. 9 would, however, remain

the same. The connection between the electric motor and the engine is made up through the road 64 between the front and rear wheels. Additionally, those skilled in the art will appreciate that there are other protection and limiting control loops that can be employed to make the CVT controller practical for all driving conditions, and that the flow diagram of FIG. 8 represents a preferred embodiment depicting the basic concept of the invention.

Referring to FIG. 9 and FIG. 10, it can be seen that if the vehicle is at a steady state at *A* and then an acceleration command ($+\Delta A_C$) is suddenly applied by the drive, then this produces torque instantly to move from steady state cruise at point *A* to power at point *B* along line L_1. Then the power at point *B* is held constant as the vehicle accelerates and the CVT transmission input speed and torque moves along line L_2 to a new steady state cruise point at point *C*. If the driver lets up on the accelerator pedal ($-\Delta A_C$) so that it returns to its original position, at point *C*, the acceleration of the vehicle suddenly changes, the power goes to point *D* along line L_3 and. the vehicle then decelerates along a lower power line L_4 back to the steady state cruise speed at point *A*. Note that the electric motor torque T_M overrides the engine torque T_E with a negative torque to force the engine to slow down to the desired power level at point *A*. To override the engine torque along the IOL, several methods can be used. One method would be to use the electric motor to directly oppose the engine by reversing polarity and drawing energy from the batteries. A second and preferred method would be to use the motor/generator in a generator mode, thereby absorbing the necessary torque and returning energy to the batteries. This constitutes an acceleration/deceleration cycle by the accelerator pedal.

Referring more particularly to FIG. 9, when the accelerator pedal is depressed to a position between 0 and A_0, for example to $A_{0.5}$, when the speed of the car is zero the control

system is operating in the torque control region shown. The control system of FIG. 8 will cause the car to accelerate at a rate proportional to this accelerator pedal position. This acceleration will remain constant and power will increase linearly until the CVT (or transmission) input speed S_T reaches the torque/power control transitory boundary line from 0,0 to A_1,S_0 at $A_{0.5}$, B. If the accelerator pedal position remains unchanged, then as the vehicle continues to accelerate, and the CVT input speed S_T increases beyond the boundary, the power of this system will remain constant and torque will decrease linearly as speed increases. This means that the torque will decrease inversely proportional to the speed increase of S_T. This decrease in torque will continue until the speed of the vehicle increases to a point where the torque required to overcome rolling friction, aerodynamic drag, and internal friction losses is equal to the commanded power. The vehicle at this point will then stop accelerating and continue at a constant speed.

Note that the arbitrary boundary in FIG. 9 which divides the operating range into a torque control region and a power control region is preferable because of the nature of the CVT and the characteristics of the motor and engine. This boundary is shown as a line between the torque speed origin and the point A_1,S_0. Another boundary which separates electric operation from hybrid operation is shown in FIG. 9 as the vertical line at point S_E minimum. This boundary, however, is arbitrary and can consist of a curve or a series of steps or a vertical line from A_1, S_0 to the speed axis at S_0. The transition from torque control to power control should be seamless to the driver of the vehicle as well as when the engine is coupled on or off. The high power electric motor is used to provide this seamless transition.

If the accelerator pedal is depressed to maximum at zero (0) speed, the torque of the motor will go to a maximum at A_0. Then, as the car accelerates, the motor torque will remains at

maximum until S_E *MIN*. At this point, if the engine control system is enabled, the engine will come "on" by closing clutch 14 (FIG. 4). The torque will then jump to A_1,S_E *MIN* and the torque of the motor and engine will remain along the maximum line until the CVT input speed S_T (which is now both the speed of the engine S_E and the speed of the motor S_M, that is S_T=S_E=S_M) reaches S_0 as the vehicle accelerates. The operating point is now A_1,S_0 which is a torque level of $T_E + T_M$ *MAX* = A_1 and a speed of S_0. This point is the maximum allowed power to the electric motor. As the speed further increases, the maximum power of the motor is added to the increasing power of the engine. These powers are additive, but the torque decreases to the point A_2,S_E *MAX* as the vehicle continues to accelerate. The electric motor maximum speed S_M *MAX* and the gasoline engine maximum speed S_E *MAX* are preferably the same. Thus, S_E *MAX* = S_M *MAX* =S_T *MAX*. Otherwise S_T *MAX* = min of (S_E *MAX* or S_M *MAX*). This point A_2,S_E *MAX* will be maintained as the vehicle continues to accelerate and the CVT ratio *R* changes. The vehicle speed continues to increase until the load and friction drag become equal to the torque at A_2,S_E *MAX* or *Scar MAX* is reached. The vehicle will then stop accelerating. Note that this will be the vehicle's top speed.

At this point if the accelerator pedal is decreased to A_3, then the torque will decrease to a level supplied by the engine alone operating on the IOL. The electric motor torque goes to zero.

If the accelerator pedal decreases further to the point A_4,S_E *MAX* which represents a lower power than the IOL of the IC engine, the speed of the engine S_E and electric motor S_M and the transmission input S_T will decrease along a constant power line to point A_4' where again the gasoline engine is supplying all the power to drive the vehicle. In order to proceed from point A_3

to point A_4, the electric motor/generator torque T_M will become negative since the term $\frac{P_C}{S_E}$ in block 126 of FIG. 8 will be negative at this instant.

We can now explain a typical operation shown in FIG. 9 in conjunction with the control diagram of FIG. 8. The vehicle is now cruising at a fixed speed when the engine is supplying all the power to drive the vehicle and the electric motor/generator is supplying no power. Consider point A in FIG. 9 in this condition of steady state operation where $P_{EP} = 0$ and $P_C = P_{IOL}$ is reached with the accelerator pedal position at A_{CA}. If the driver suddenly depresses the pedal to a second position, which will be designated as A_{CB}, meaning the driver wants to increase power, the torque increases instantly to point B along line L_1 with torque supplied by the electric motor and battery. This is so because P_{EP} is now greater than P_{IOL}. Then T_M is computed in block 114 if the vehicle is in the electric mode or block 126 if vehicle is in the hybrid mode. It will be appreciated that at this instant that $\dot{R} = 0$. Then P_C/S_E supplies all necessary torque in electric mode and $P_C/S_E - T_{IOLE}$ or $T_C - T_{IOLE}$ supplies all of the torque if in the hybrid mode. This motor torque signal is transmitted to block 102. The power desired by the driver is then achieved instantly. If the accelerator pedal is held constant at this point over time, then the torque of the electric motor will decrease along a line of constant power along line L_2 in FIG. 9, thus holding the power constant as the vehicle accelerates. This line L_2 represents the action of the feedback loop as designed in FIG. 8 which includes blocks 102, 104, 106, 108 and 110 (or 128 and 130), and 114 or 126. The vehicle will continue to accelerate with motor torque decreasing along line L_2 until the point C is reached along the constant power line L_2. This point is reached when P_{EP} is iteratively reduced to zero and $P_C = P_{IOL}$. It will be appreciated that at all times during this

process, the engine always operates along the IOL.

The car then will maintain this speed until the position of accelerator pedal is again changed. If the accelerator pedal is now reduced to the original position, the net torque will be reduced to point *D*, and speed will proceed back to point *A* along a constant power line L_4. To accomplish this, the electric motor/generator must supply a negative torque to reach point *D* along line L_3. This happens instantly. As the net torque and power proceeds along line L_4, the electric motor/generator torque gradually approaches zero as the vehicle again begins to cruise when the accelerator position returns to A_{CA}. Note that in this preferred mode the deceleration maneuver returns energy to the battery system described above, and the acceleration maneuver takes energy from the battery system while the engine continues to operate along the IOL.

It will be appreciated, therefore, that the throttle opening of the engine is set to provide the best efficiency for a given power along the *IOL*. The electric motor is used to force the engine to operate along the *IOL* and to provide correct transient response to the vehicle. Note that a large electric motor and a small engine is preferred, but the invention can also employ a large engine and small electric motor with slower response. The CVT provides the correct speed and power setting as quickly as dynamics and motor capacity allow. The battery capacity is then used to temporarily provide and absorb energy to allow the CVT to change ratio without detrimental effects on performance. It will further be appreciated that this is accomplished, in the preferred embodiment, by having the engine and the electric motor on the same shaft in the preferred embodiment.

Based on the foregoing, it will be appreciated that the present invention can take advantage of the electric motor in a common shaft hybrid electric power train in a way heretofore

unknown. The electric motor can be used to supplement and control the gasoline or diesel engine during both acceleration and deceleration of the vehicle, thus allowing the engine to run at optimum efficiency across its entire speed band with generally a fixed throttle setting or in an un-throttled state so as to maximize engine efficiency. This is not possible in a conventional continuously variable transmission system as discussed in FIG. 1.

Referring also to FIG. 11 and FIG. 12, control of the accelerator pedal provides instant torque compensation as well as power control in the steady state in the example power cycle described above. The power during the transition time from t_0 to t_1 is supplied from the battery pack in the preferred embodiment. The power absorbed during the transition time from t_1 to t_2 is fed back into the battery pack. The battery pack should be large enough to keep its internal resistance low, so that the modulation of the accelerator pedal uses a minimum percentage of the total energy to and from the battery pack, thus extending the range on a battery charge. The main battery pack can be charged off-board by stationary power plants if desired. This concept is especially important while the car is being driven at highway speeds because the power required may make gasoline or diesel more efficient to use than electricity. For city driving in the hybrid mode, this concept is also used to extend range.

We can now explain braking the vehicle with a brake command *Bc* in FIG. 8. As the brake pedal is depressed for a normal stop, switches SW1 and SW2 in FIG. 8 are set to the brake position. The braking level desired by the driver is compared with the ideal regeneration line (IRL) at block 118 at a given vehicle speed and transmission input speed S_T or motor speed S_M.

The IRL is a line determined by testing the motor/generator and battery system for the best efficiency for energy storage at each speed. After such testing procedure, an ideal line can

be selected to connect all the best efficiency points yielding the IRL.

The brake command Bc (at 34 in FIG. 8) represents a desired torque at the drive shaft or wheels of the car. At block 122 the torque command is divided by the ratio R to obtain the equivalent torque at the CVT input 124. This input is compared with the torque along the IRL at the speed of the motor S_M at this instant. The error is used to command $\dot{R}$ through the gain block 120 and filter block 112. The ratio R of the transmission will change to seek the IRL via the feedback control system of blocks 102, 104, 106, 112, 116, 118 and 120. It is understood that this control system becomes ineffective when the ratio reaches its physical limits *Rmin* or *Rmax* in either acceleration or braking mode.

The desired torque at the output of block 122 is sent to block 100 to compute the motor torque necessary to achieve the desired braking torque at the driveshaft and consequently the wheels of the car. Initially the torque at the motor is T_C/R since $\dot{R}$ is zero at the start of the maneuver.

The braking torque as a function of vehicle speed is shown in FIG. 13. This figure shows the torque command T_C for the drive shaft. The maximum allowable safe electrical regeneration braking torque is set at 100%. If more torque is required, the brake pedal then commands the standard hydraulic mechanical brakes, which are used for panic stops, to hold the car at zero speed and emergency and parking.

Accordingly, it will be seen that this invention provides for simultaneous control of the acceleration of a vehicle and the torque and speed of the engine in a vehicle, and allows the engine to always operate at a best throttle or along the best efficiency (ideal speed/torque)

operating line, thereby reducing the emissions of the engine and providing the best possible efficiency and lowest emissions, or operating the engine in accordance with any other desired operating characteristics. It also provides the possibility of operating the electric traction motor at its optimum efficiency during acceleration, braking and cruising when operating in the electric car mode. Furthermore, the invention described herein is application to "mild hybrids" as well as charge depletion hybrids described in my prior patent, U.S. No. 5,842,534. Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. Thus the scope of this invention should be determined by the appended claims and their legal equivalents.

CLAIMS

What is claimed is:

1. An apparatus for controlling the power at the output of an internal combustion engine, comprising:

(a) an electric motor coupled to the output of said engine; and

(b) a motor controller which varies engine power output with said electric motor.

2. An apparatus as recited in claim 1, wherein said motor comprises a motor/generator.

3. An apparatus as recited in claim 1, wherein said motor controller varies positive and negative output torque of said electric motor to vary engine power output.

4. An apparatus as recited in claim 1 wherein, for any given speed, said motor controller sets engine power output in accordance with predetermined operating characteristics.

5. An apparatus as recited in claim 1, wherein said motor is coupled to a transmission.

6. An apparatus as recited in claim 5, wherein the rate of change of ratio of said transmission is controllable and further comprising means for controlling the rate of change of ratio.

7. An apparatus as recited in claim 6, wherein said transmission is a continuously variable transmission.

8. An apparatus as recited in claim 6, wherein said transmission is an automatic transmission.

9. An apparatus for controlling the power at the output of an internal combustion engine coupled to a transmission wherein the rate of change of ratio of said transmission is controllable, comprising:

(a) an electric motor positioned between said engine and said transmission; and

(b) a controller which varies torque output of said electric motor and the rate of change of the ratio of said transmission wherein, for any given speed, the controller sets engine power output in accordance with predetermined operating characteristics.

10. An apparatus as recited in claim 9, wherein said transmission is a continuously variable transmission.

11. An apparatus as recited in claim 9, wherein said transmission is an automatic transmission.

12. An apparatus for controlling the power at the output of an internal combustion engine, comprising:

(a) a generator coupled to the output of said engine; and

(b) a generator controller which varies engine power output with said generator.

13. An apparatus as recited in claim 12, wherein said generator comprises a generator/motor.

14. An apparatus as recited in claim 12, wherein said generator controller varies positive and negative output torque of said generator to vary engine power output.

15. An apparatus as recited in claim 12 wherein, for any given speed, said generator controller sets engine power output in accordance with predetermined operating characteristics.

16. An apparatus as recited in claim 12, further comprising:

(a) an electric motor; and

(b) a motor controller which varies the torque of said motor;

(c) wherein said generator, said generator controller, said motor and said motor controller function as an electric continuously variable transmission.

17. An apparatus as recited in claim 16, wherein said motor comprises a motor/generator.

18. An apparatus as recited in claim 16, wherein the rate of change of ratio in said electric continuously variable transmission is controllable and further comprising means for controlling the rate of change of ratio.

19. A control apparatus for an internal combustion engine driving a continuously variable transmission and a driveshaft coupled to said continuously variable transmission wherein the rate of change of ratio of said continuously variable transmission is controllable, comprising:

(a) a generator/motor mechanically coupled to and driven by said engine;

(b) a generator/motor controller electrically connected to said generator;

(c) a motor/generator mechanically coupled to said drive shaft;

(d) a battery electrically connected to said generator/motor controller and said motor/generator controller;

(e) said generator/motor, said generator/motor controller, said motor/generator, said motor/generator controller, and said battery comprising said continuously variable transmission; and

(f) a controller which varies torque output of said generator/motor and the rate of change of the ratio of said continuously variable transmission wherein, for any given speed, said controller sets engine power output in accordance with predetermined operating characteristics.

20. A control apparatus for a vehicle having an internal combustion engine driving a transmission, wherein said transmission has an output driving a first wheel at a first end of said vehicle wheel, and wherein the rate of change of ratio of said transmission is controllable, comprising:

(a) an electric motor driving a second wheel at a second end of said vehicle;

(b) a motor controller electrically connected to said motor;

(c) said motor coupled to said transmission through a road surface; and

(d) control means for varying torque output of said motor and for varying the rate of change of the ratio of said continuously variable transmission wherein, for any given speed, said control means sets engine power output in accordance with predetermined operating characteristics.

21. A control apparatus for a vehicle having an electric motor driving a transmission and a battery system powering the electric motor, comprising a motor controller electrically connected to said electric motor wherein said motor controller varies torque output of said motor to be on an ideal operating line as determined by empirical testing of the electric motor and battery system.

22. A control apparatus for a vehicle having an internal combustion engine and an electric motor, wherein said internal combustion engine and said electric motor are coupled to a continuously variable transmission, and wherein the rate of change of ratio of said continuously variable transmission is controllable, comprising:

(a) an engine controller mechanically connected to said internal combustion engine;

(b) a motor controller electrically connected to said electric motor; and

(c) control means associated with said engine controller and said motor controller for varying torque output of said motor and for varying rate of change of the ratio of said transmission wherein, for any given speed, said control means sets engine power output in accordance with predetermined operating characteristics, and wherein said control programming includes hybrid, electric, and braking modes.

ABSTRACT OF THE DISCLOSURE

A method and apparatus for controlling the power output of an internal combustion engine in a vehicle, wherein a motor/generator or a generator/motor is coupled to the output shaft of the engine and the positive and negative torque of the motor/generator or the generator/motor is varied to control the power output of the engine as a function of speed for all manners of performance of the vehicle. The engine operates along a predetermined ideal operating line at all speeds of the vehicle.

DRAWING(S)

There is attached nine (9) sheets of drawings.

EXECUTED OATH OR DECLARATION

An executed declaration is attached.

SEQUENCE LISTING

Not Applicable

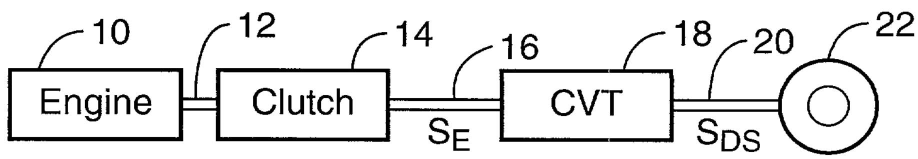

FIG. – 1
(Prior Art)

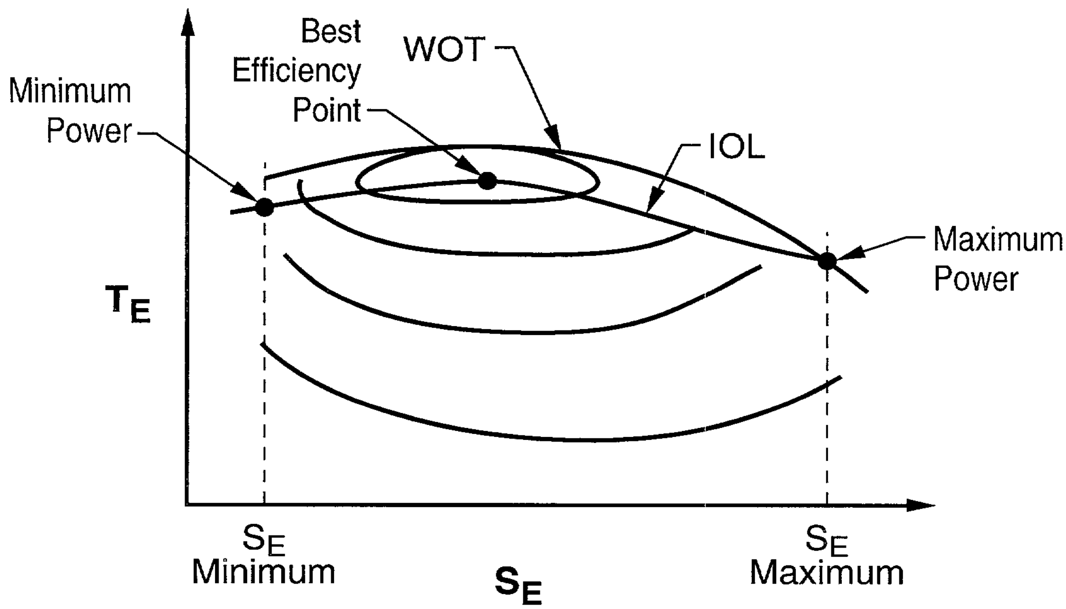

FIG. – 2

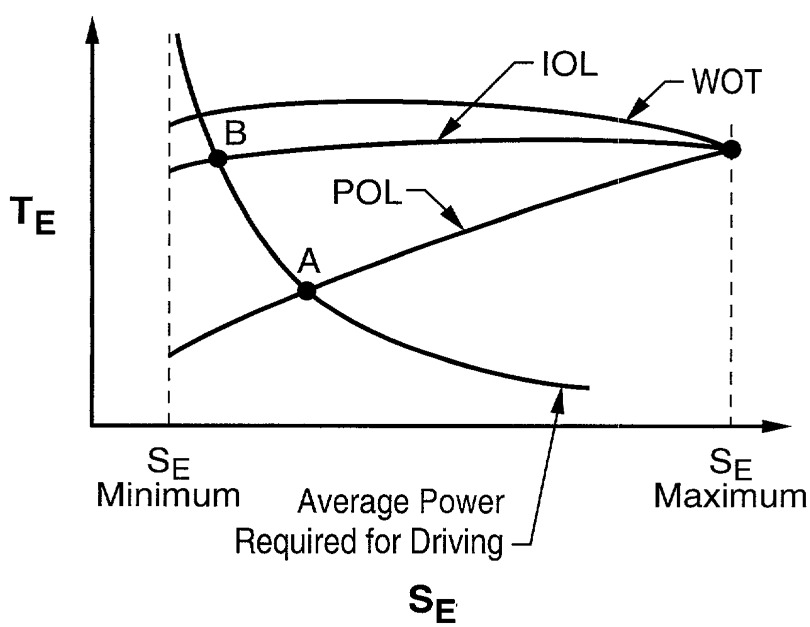

FIG. – 3

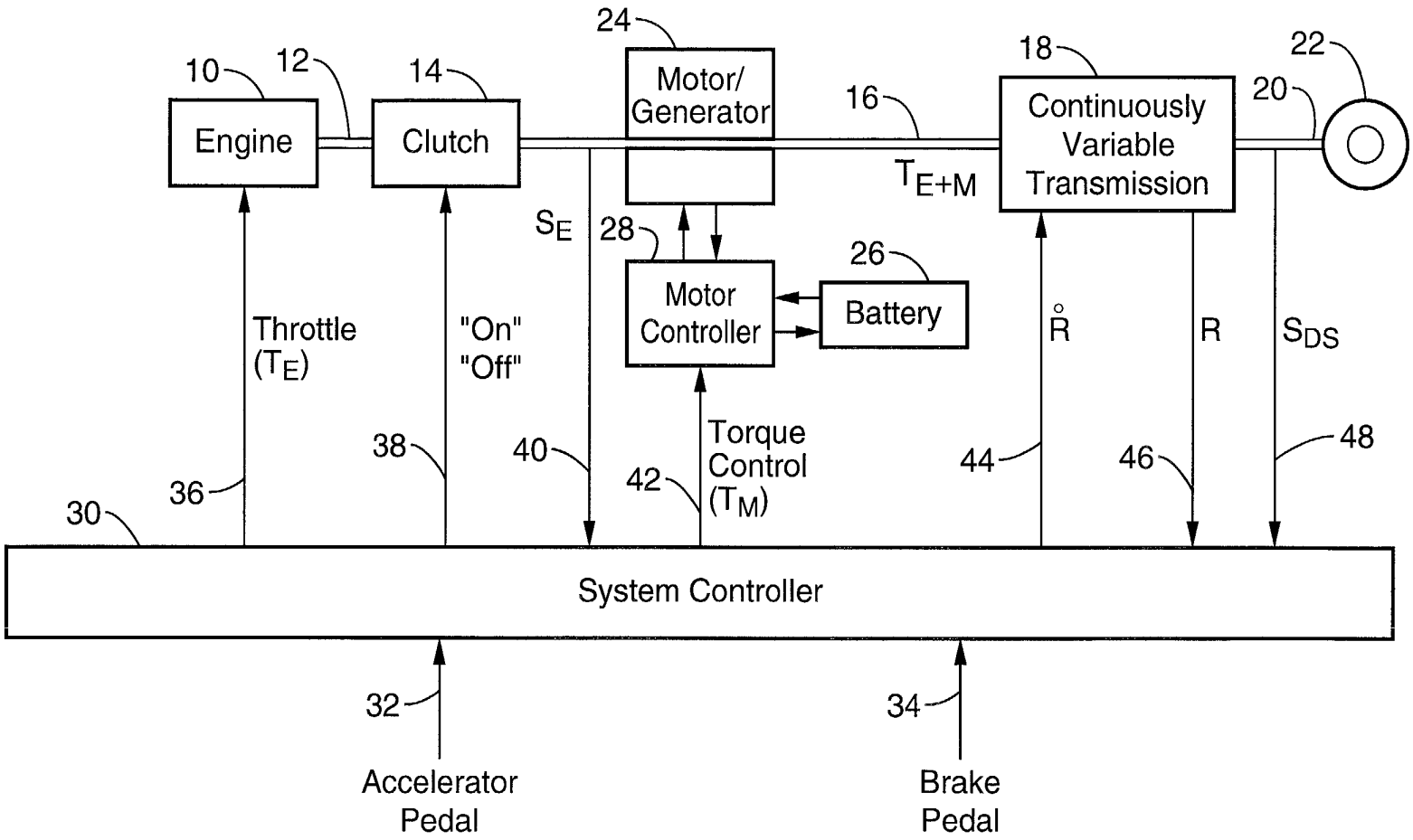
24
Motor/
Generator
10
12
14
18
22
20
16
Engine
Clutch
Continuously
Variable
Transmission
T_{E+M}
S_E
28
26
Motor
Controller
Battery
Throttle
(T_E)
"On"
"Off"
$\dot{R}$
R
S_{DS}
Torque
Control
(T_M)
38
40
42
44
46
48
36
30
System Controller
32
34
Accelerator
Pedal
Brake
Pedal

FIG. – 4

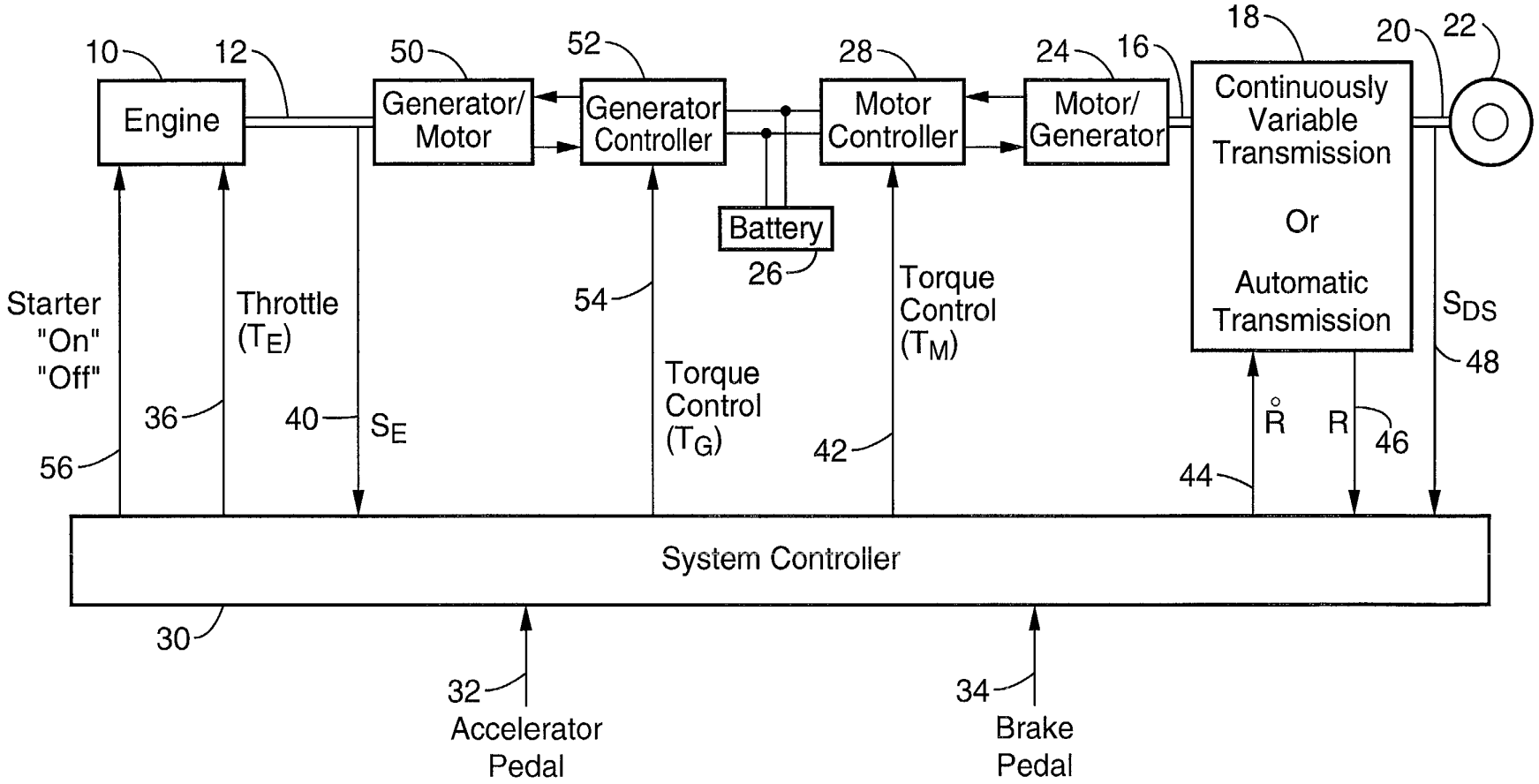
10
12
50
52
28
24
16
18
20
22
Engine
Generator/ Motor
Generator Controller
Motor Controller
Motor/ Generator
Continuously Variable Transmission
Or
Automatic Transmission
Battery
26
54
Starter "On" "Off"
Throttle (T_E)
Torque Control (T_G)
Torque Control (T_M)
S_{DS}
48
36
40
S_E
42
R
R
46
44
56
System Controller
30
32
Accelerator Pedal
34
Brake Pedal

FIG. – 5

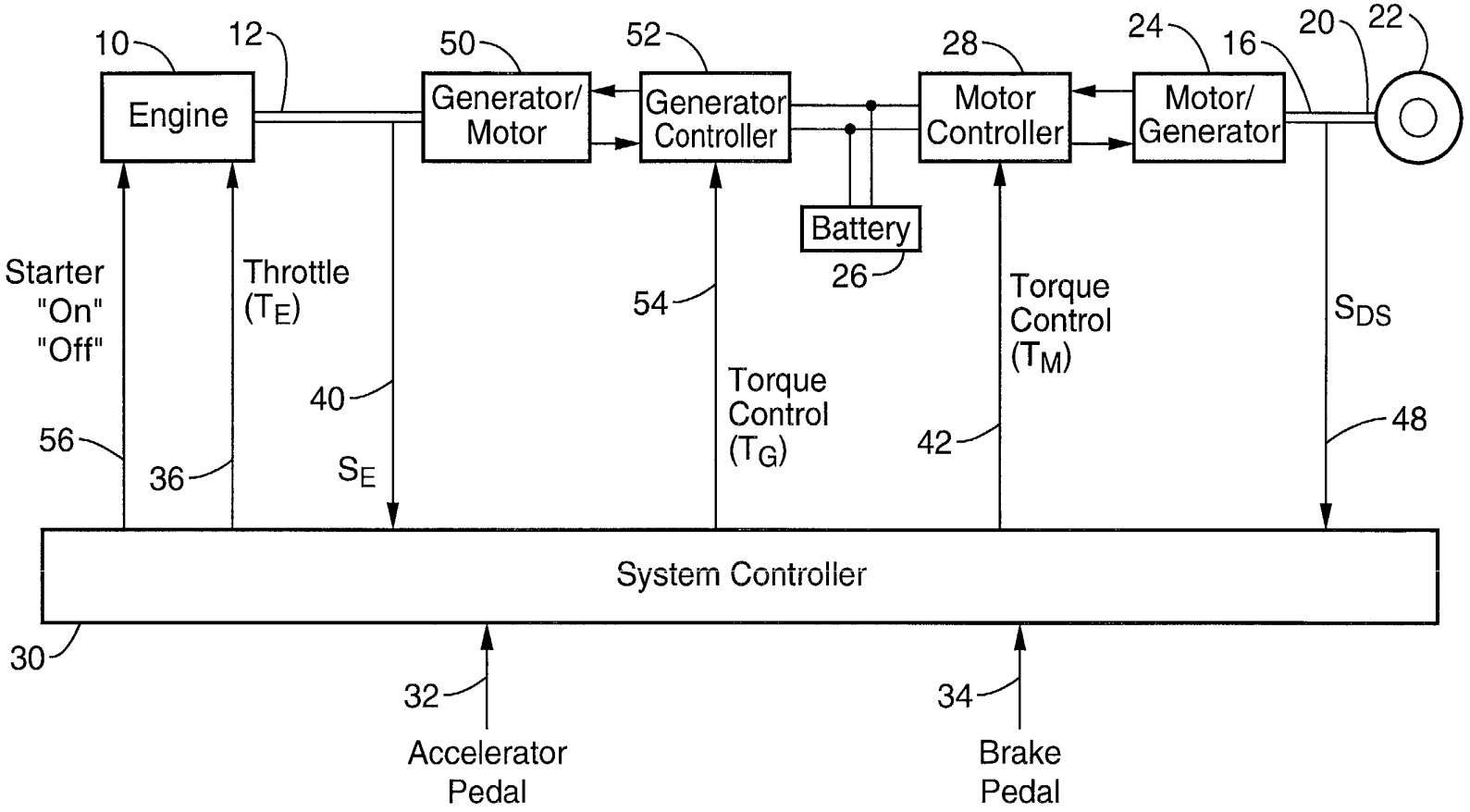
10
12
50
52
28
24
16
20
22
Engine
Generator/
Motor
Generator
Controller
Motor
Controller
Motor/
Generator
Battery
26
Starter
"On"
"Off"
Throttle
(T_E)
54
Torque
Control
(T_M)
S_{DS}
40
Torque
Control
(T_G)
56
36
S_E
42
48
System Controller
30
32
34
Accelerator
Pedal
Brake
Pedal

FIG. – 6

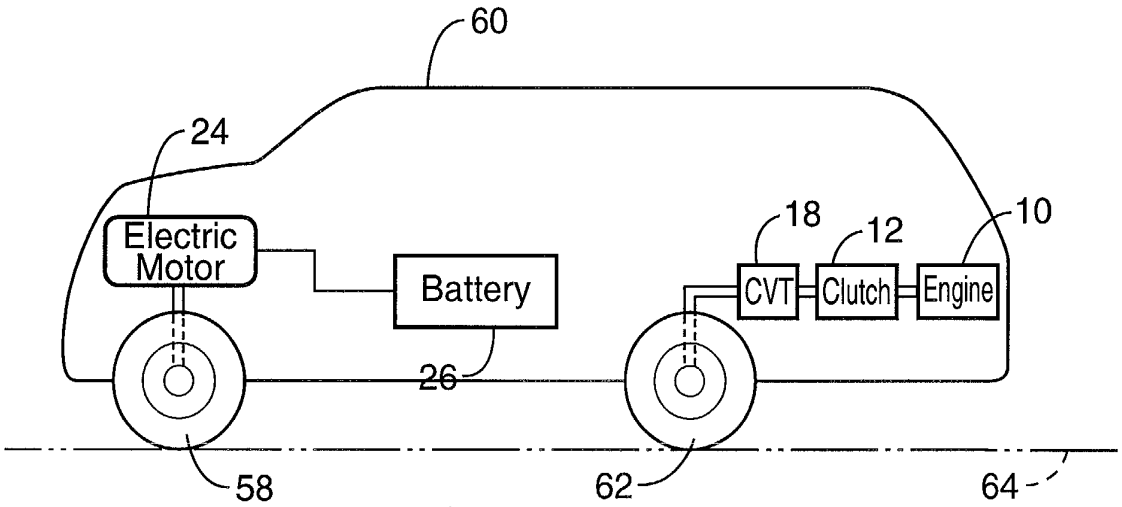
60
24
Electric Motor
Battery
26
18
12
10
CVT
Clutch
Engine
58
62
64

FIG. – 7

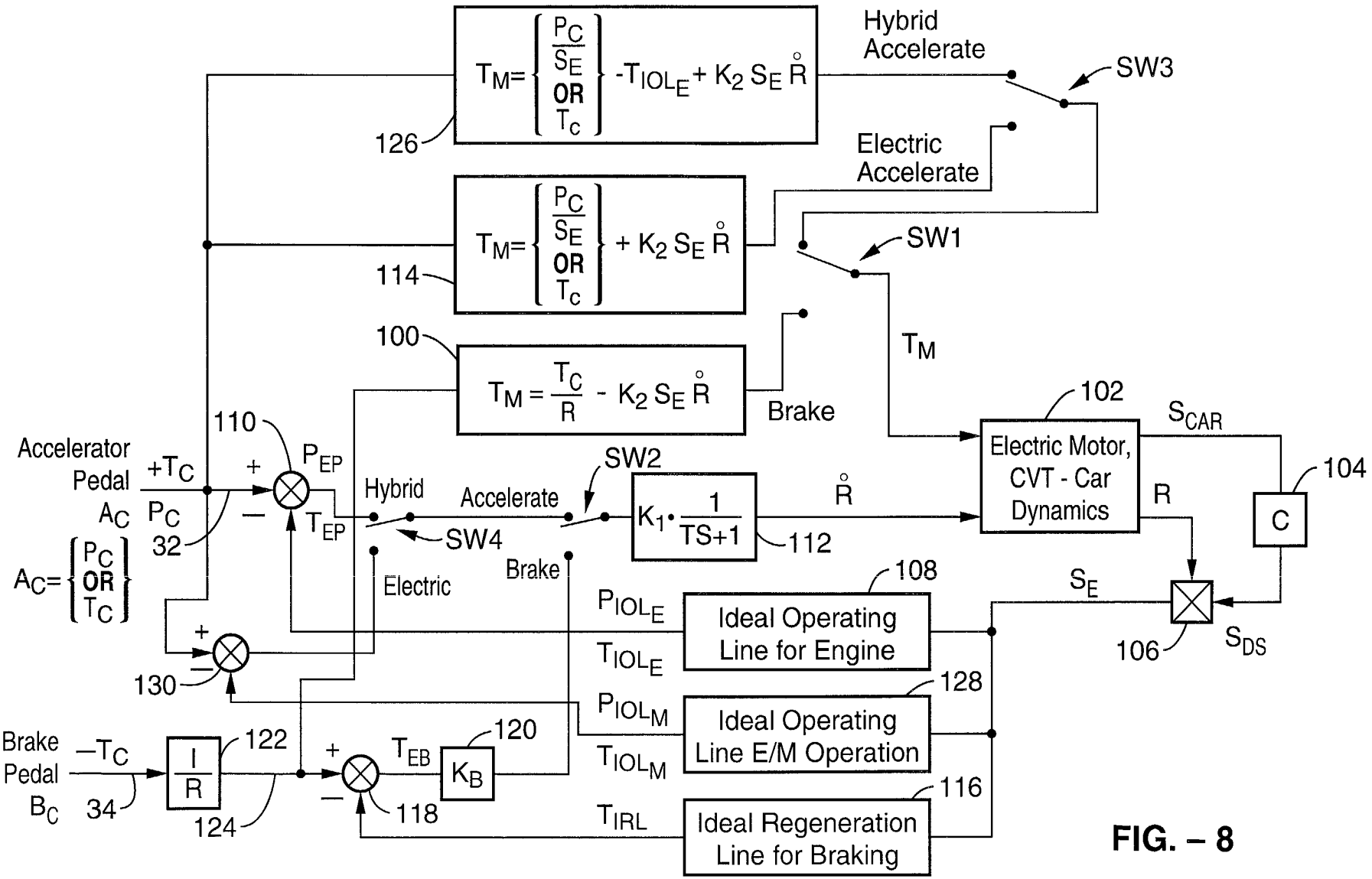
$T_M = \left\{ \frac{P_C}{S_E} \text{ OR } T_C \right\} - T_{IOL_E} + K_2 S_E \dot{R}$
126
Hybrid Accelerate
SW3
Electric Accelerate
$T_M = \left\{ \frac{P_C}{S_E} \text{ OR } T_C \right\} + K_2 S_E \dot{R}$
114
SW1
T_M
100
$T_M = \frac{T_C}{R} - K_2 S_E \dot{R}$
Brake
102
Electric Motor, CVT - Car Dynamics
S_{CAR}
104
C
R
110
Accelerator Pedal
$+T_C$
P_C
A_C
32
$A_C = \left\{ \frac{P_C}{OR} \right\}$
T_C
P_{EP}
T_{EP}
Hybrid
Accelerate
SW2
SW4
$K_1 \cdot \frac{1}{TS+1}$
112
$\dot{R}$
Electric
Brake
108
P_{IOL_E}
T_{IOL_E}
Ideal Operating Line for Engine
S_E
106
S_{DS}
130
128
P_{IOL_M}
T_{IOL_M}
Ideal Operating Line E/M Operation
Brake Pedal
$-T_C$
B_C
34
$\frac{I}{R}$
122
124
T_{EB}
K_B
120
118
116
T_{IRL}
Ideal Regeneration Line for Braking

FIG. – 8

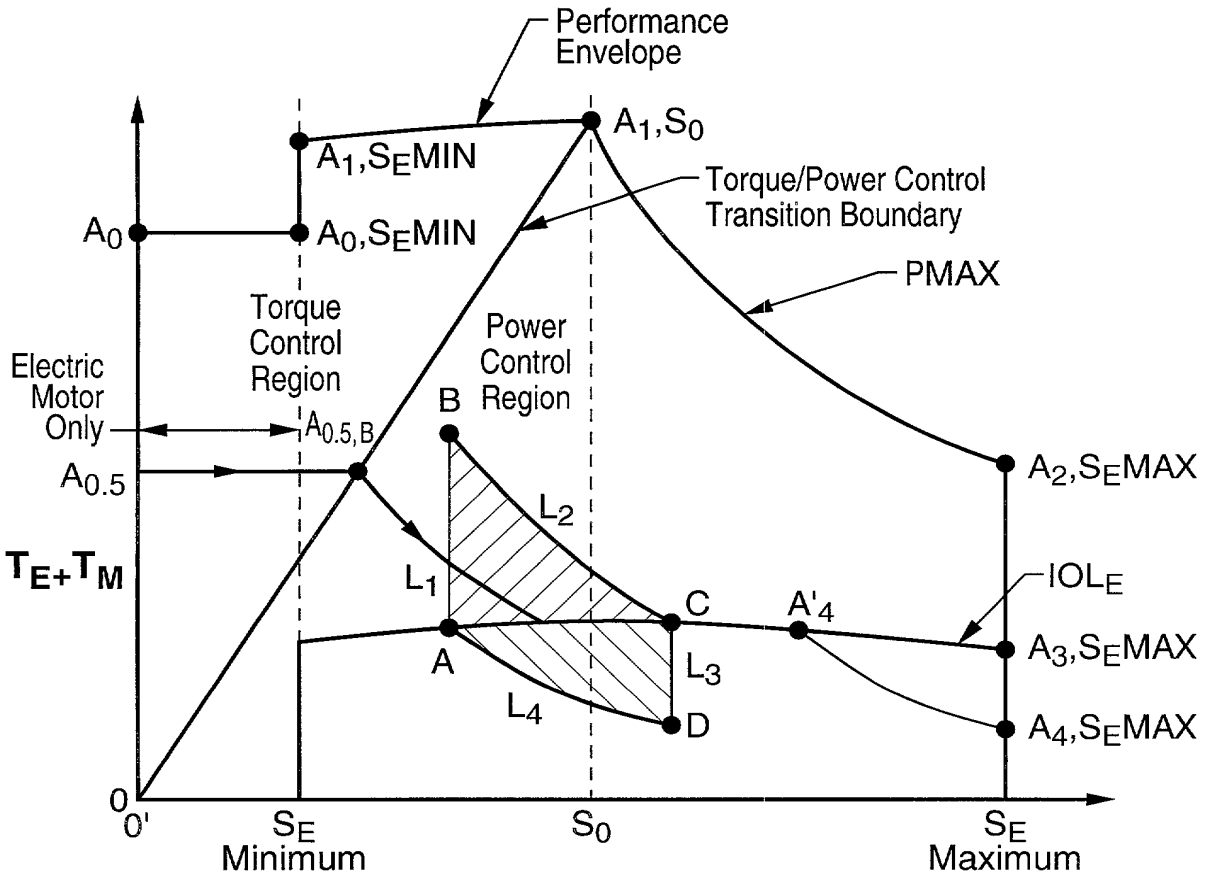
Performance Envelope
A1,S0
A1,SEMIN
Torque/Power Control Transition Boundary
A0
A0,SEMIN
PMAX
Torque Control Region
Power Control Region
Electric Motor Only
B
A0.5,B
A2,SEMAX
A0.5
L2
TE+TM
L1
IOLE
C
A'4
A3,SEMAX
A
L3
L4
D
A4,SEMAX
0
0'
SE Minimum
S0
SE Maximum
ST

FIG. – 9

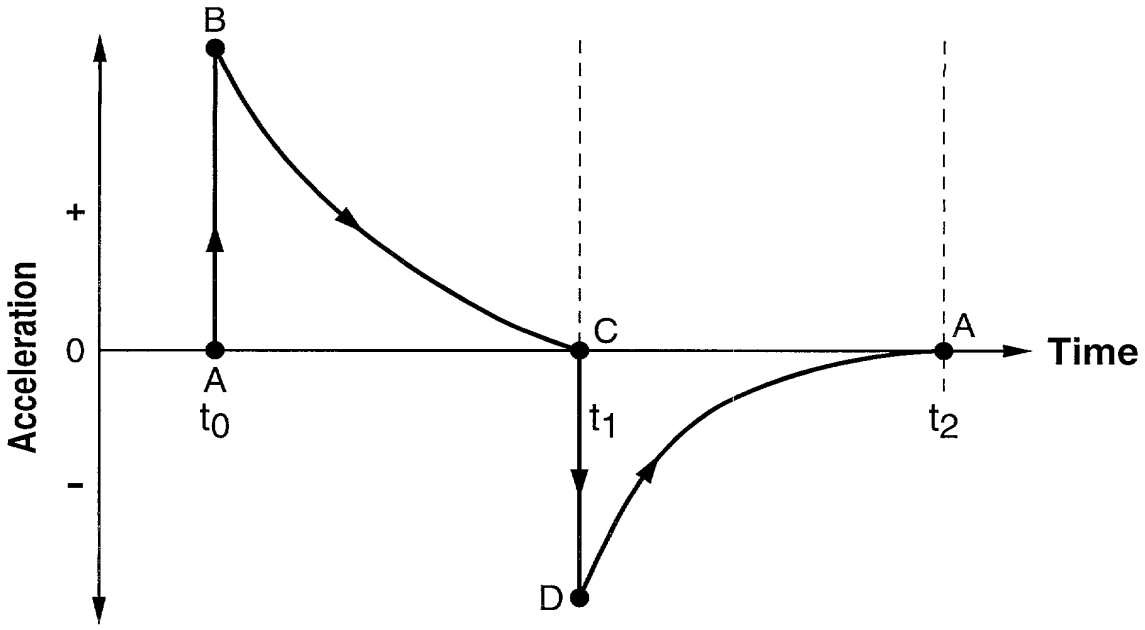

FIG. – 10

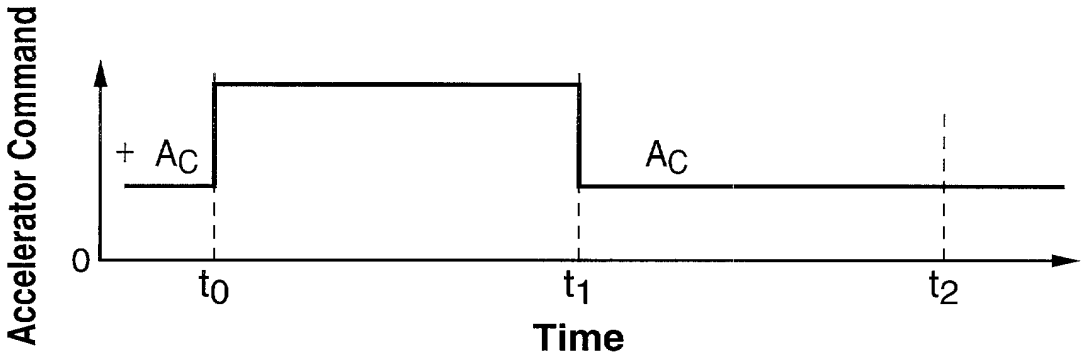

FIG. – 11

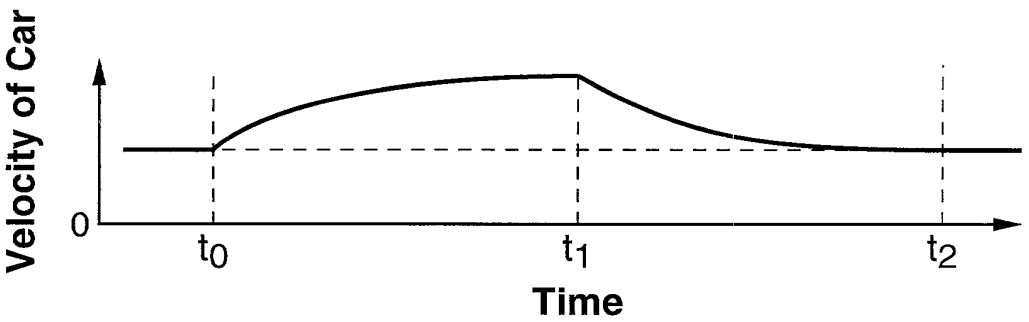

FIG. – 12

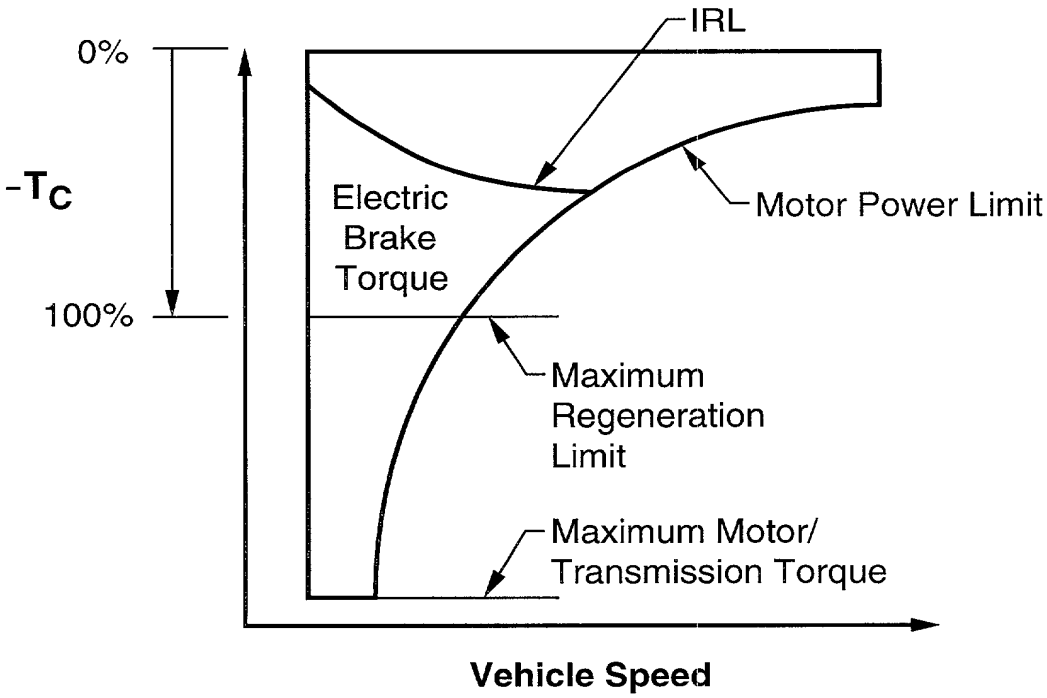

FIG. – 13

PATENT

Applicant: ANDREW A. FRANK
Serial No.:
Filed:
Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Group:
Examiner:
Docket No. UC98-194-2US

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, SUPPLEMENTAL, NATIONAL STAGE OF PCT, DIVISIONAL, CONTINUATION OR CONTINUATION-IN-PART)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is of the following type:

_ original (regular)

_ design

X supplemental-continuation of PCT Application in the U.S.

NOTE: If the declaration is for an International Application being filed as a divisional, continuation, or continuation-in-part, do not check the next item; check appropriate one of last three items.

_ national stage of PCT

_ divisional

_ continuation

_ continuation-in-part

INVENTORSHIP IDENTIFICATION

WARNING: If the inventors are each not the inventors of all of the claims, an explanation of the facts, including the ownership of all the claims at the time the last claimed invention was made, should be submitted.

My residence, post office address, and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention described in

SPECIFICATION IDENTIFICATION

[ ] the specification filed herewith by the above-named inventors, with the title listed above.

[X] the specification filed herewith by the above-named inventors, with the title listed above, and which was amended by the Preliminary Amendment filed herewith.

[ ] the specification identified above, as amended by the Preliminary Amendment filed herewith.

[ ] the specification identified above, and which was amended on _____.

[X] PCT International Application No. PCT/US99/09880 filed on 19 APRIL 1999, and amended under PCT Article 19 on ____N/A____ (if applicable).

ACKNOWLEDGMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. § 1.56.

PRIORITY CLAIM (35 U.S.C. § 119(a)-(d))

I hereby claim foreign priority benefits under 35 U.S.C. §§ 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or under 35 U.S.C. § 365(b) of any PCT international application(s) designating at least one country other than the United States of America listed below, and have also identified below any foreign application(s) or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

X no such applications have been filed.

__ such application have been filed as follows.

PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119(a)-(d)

COUNTRY (OR INDICATE IF PCT)	APPLICATION NUMBER	FILING DATE (day, month, year)	PRIORITY CLAIMED UNDER 37 U.S.C. § 119
			__ YES __ NO
			__ YES __ NO
			__ YES __ NO
			__ YES __ NO

CLAIM FOR BENEFIT OF PRIOR U.S. PROVISIONAL APPLICATION(S)
(35 U.S.C. § 119(e))

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional applications (s) listed below:

PROVISIONAL APPLICATION SERIAL NUMBER	FILING DATE OF PROVISIONAL APPLICATION

CLAIM FOR BENEFIT OF EARLIER U.S./PCT APPLICATIONS
UNDER 35 U.S.C. 120

(complete this part only if this is a divisional, continuation, CIP or national stage of PCT)

I/We hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability under 37 C.F.R.§ 1.56, which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application.

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

1. **U.S. Applications:**

SERIAL NUMBER	FILING DATE
09/063,993	**21 APRIL 1998**

2. **PCT Applications Designating The U.S.**

PCT APPLICATION NUMBER	PCT FILING DATE	U.S. SERIAL NUMBER
PCT/US99/09880	**19 APRIL 1999**	

POWER OF ATTORNEY

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith.

John P. O'Banion	Registration No. 33,201
James M. Ritchey	Registration No. 32,594
Steven L. Smith	Registration No. 44,343
Rodger H. Rast	Registration No. 45,853

__ Attached as part of this declaration and power of attorney is the authorization of the above-named attorney to accept and follow instructions from my representative(s).

SEND CORRESPONDENCE TO:

John P. O'Banion
O'BANION & RITCHEY LLP
400 Capitol Mall, Suite 1550
Sacramento, CA 95814

DIRECT TELEPHONE CALLS TO:

John P. O'Banion
(916) 498-1010

DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE(S)

Full name of sole or first inventor: ANDREW A. FRANK

Inventor's Signature: Andrew A. Frank

Date: 9/19/00 Country of Citizenship: UNITED STATES

Residence: EL MACERO, CALIFORNIA

P.O. Address: 44578 COUNTRY CLUB DRIVE, EL MACERO, CA 95618

Full name of second joint inventor, if any:

Inventor's Signature: _____

Date: _____ Country of Citizenship: UNITED STATES

Residence:

P.O. Address:

CHECK PROPER BOX(ES) FOR ANY OF THE FOLLOWING ADDED PAGE(S) WHICH FORM A PART OF THIS DECLARATION

__ Signature for third and subsequent joint inventors.
Number of pages added __________.

__ Signature by administrator(trix), executor(trix) or legal representative for deceased or incapacitated inventor.
Number of pages added __________.

__ Signature for inventor who refuses to sign or cannot be reached by person authorized under 37 CFR 1.47.
Number of pages added __________.

__ Signature by one joint inventor on behalf of deceased inventor(s) where legal representative cannot be appointed in time under 37 CFR 1.47.
Number of pages added __________.

__ Authorization of attorney(s) to accept and follow instructions from representative.

X **This Declaration ends with this page.**

PATENT

Applicant: ANDREW A. FRANK
Serial No.:
Filed:
Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Group:
Examiner:
Docket No. UC98-194-2US

POWER OF ATTORNEY BY ASSIGNEE AND EXCLUSION OF INVENTOR(S) UNDER 37 C.F.R. 3.71

Dear Sir:

The undersigned assignee of the entire interest in the above-identified subject application hereby appoints

John P. O'Banion, Reg. No. 33,201

as its attorney to prosecute this application and to transact all business in the United States Patent and Trademark Office connected therewith, said appointment to be to the exclusion of the inventors and their attorney(s) in accordance with the provisions of 37 C.F.R. 3.71.

An assignment of the entire interest in the above-identified subject application:

[ ] was recorded on _____ at reel/frame _____/_____.

[X] is submitted herewith for recording.

Please direct all telephone calls to John P. O'Banion at (916) 498-1010 and all correspondence relative to said application to the following address:

John P. O'Banion, Esq.
O'BANION & RITCHEY LLP
400 Capitol Mall, Suite 1550
Sacramento, CA 95814

Dated: September 22, 2000

ASSIGNEE: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

Signature: Linda S Stevenson

Typed Name: Linda S. Stevenson

Title: Manager, Patent Prosecution
Office of the President
University of California
1111 Franklin Street, 5th Floor
Oakland, CA 94607-5200

PATENT

Applicant: ANDREW A. FRANK
Serial No.:
Filed:
Title: CONTROL METHOD AND APPARATUS FOR INTERNAL COMBUSTION ENGINE ELECTRIC HYBRID VEHICLES
Group:
Examiner:
Docket No. UC98-194-2US

ASSIGNEE CERTIFICATION UNDER 37 C.F.R. 3.73(b)

In accordance with 37 C.F.R. 3.73(b), the assignee hereby certifies that the evidentiary documents with respect to its ownership have been reviewed and that, to the best of the assignee's knowledge and belief, title is in the assignee seeking to take this action.

Dated: September 22, 2000

ASSIGNEE: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

Signature: Linda S Stevenson

Typed Name: Linda S. Stevenson

Title: Manager, Patent Prosecution
Office of the President
University of California
1111 Franklin Street, 5th Floor
Oakland, CA 94607-5200